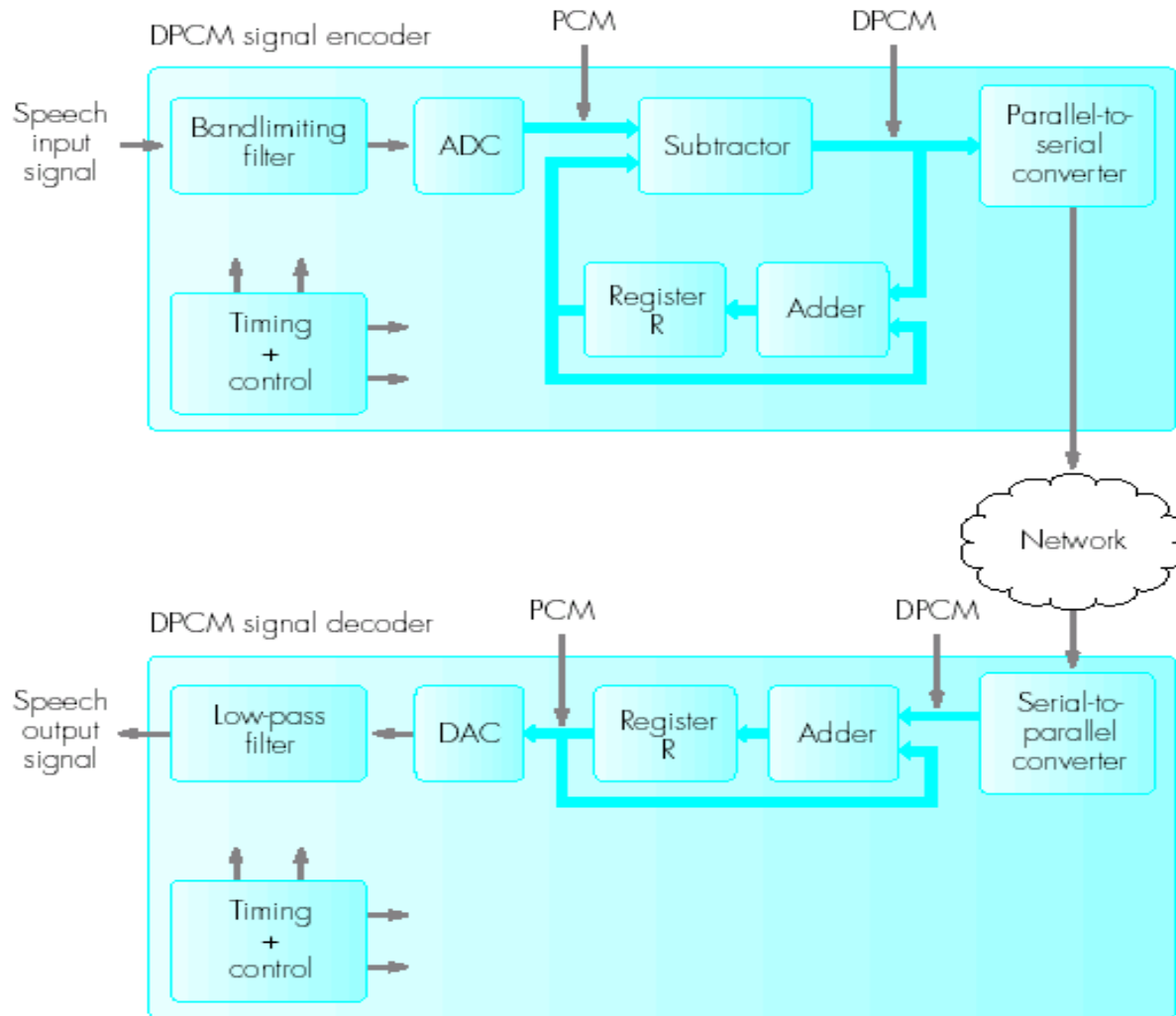
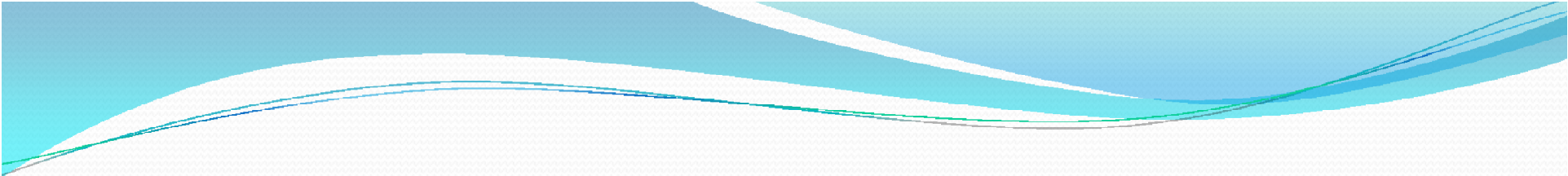


**Differential Pulse Code Modulation
(DPCM)
&
Delta Modulation
(DM)**

Audio Compression- DPCM Principles



- 
- Differential pulse code modulation is a derivative of the standard PCM
 - It uses the fact that the range of differences in amplitudes between successive samples of the audio waveform is less than the range of the actual sample amplitudes
 - Hence fewer bits to represent the difference signals

Operation of DPCM

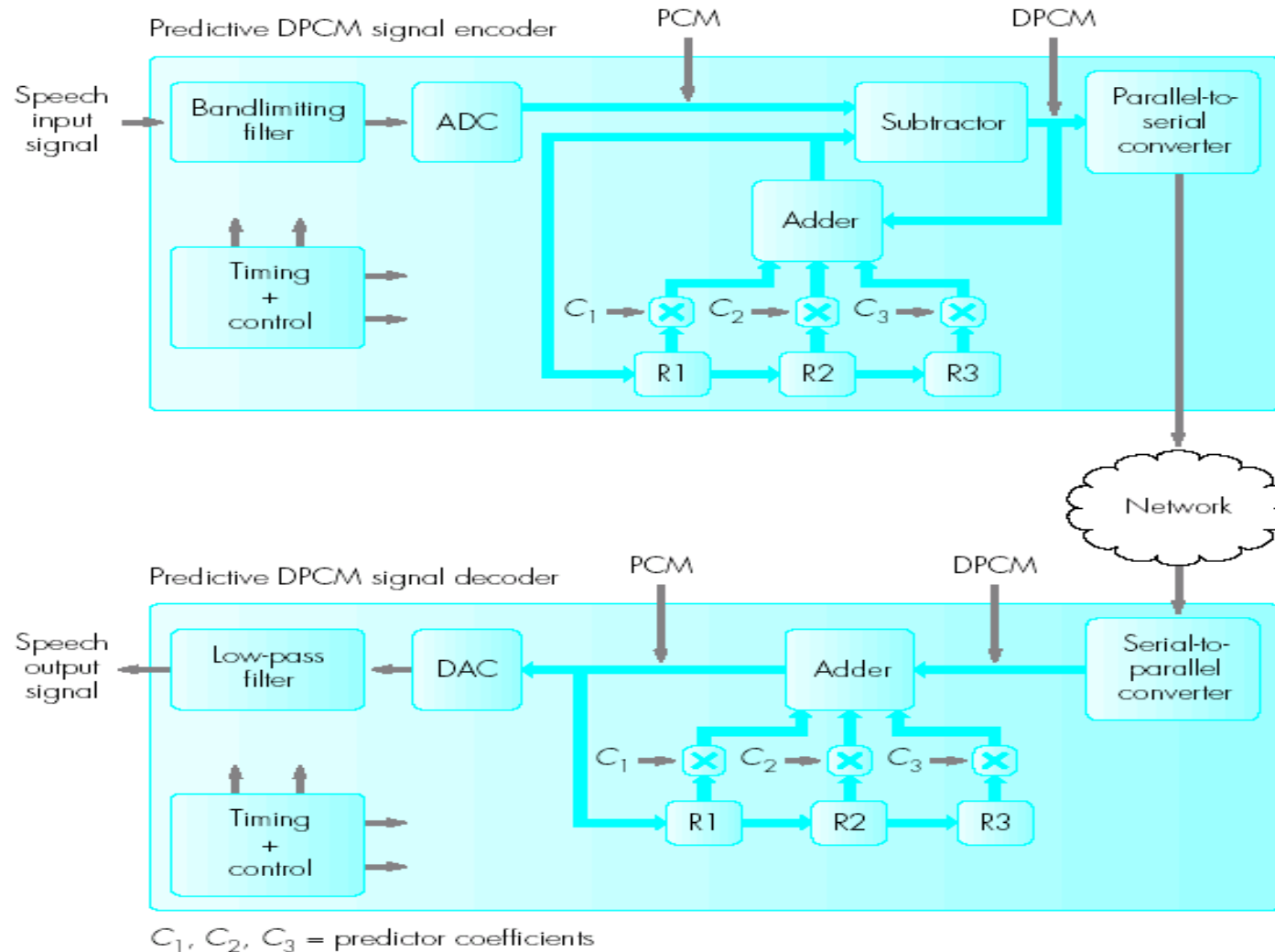
Encoder

- Previously digitized sample is held in the register (R)
- The DPCM signal is computed by subtracting the current contents (R_o) from the new output by the ADC (PCM)
- The register value is then updated before transmission

Decoder

- Decoder simply adds the previous register contents (PCM) with the DPCM
- Since ADC will have noise there will be cumulative errors in the value of the register signal

Audio Compression- Third-order predictive DPCM signal encoder and decoder



Operation of DPCM

- To eliminate this noise effect predictive methods are used to predict a more accurate version of the previous signal (use not only the current signal but also varying proportions of a number of the preceding estimated signals)
- These proportions used are known as **predictor coefficients**
- Difference signal is computed by subtracting varying proportions of the last three predicted values from the current output by the ADC

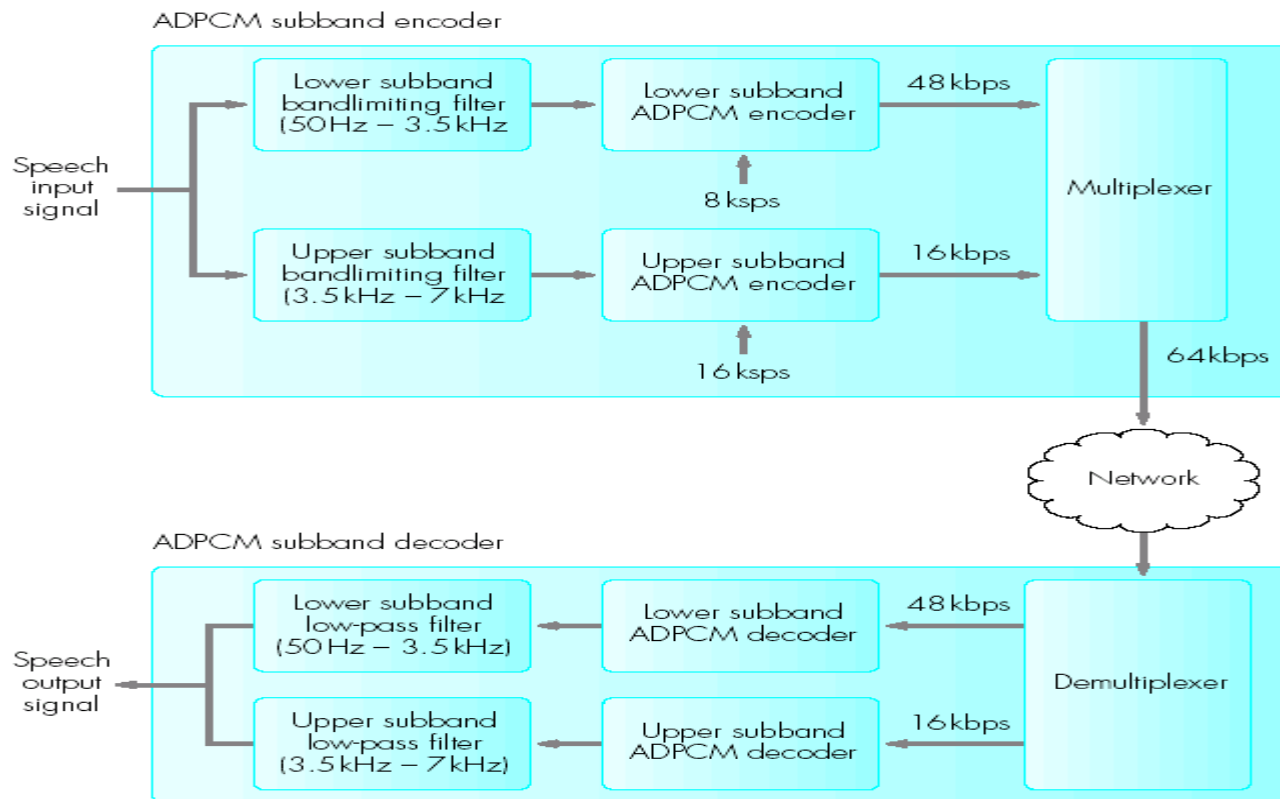
Operation of DPCM

- R_1, R_2, R_3 will be subtracted from PCM
- The values in the R_1 register will be transferred to R_2 and R_2 to R_3 and the new predicted value goes into R_1
- Decoder operates in a similar way by adding the same proportions of the last three computed PCM signals to the received DPCM signal

Adaptive differential PCM (ADPCM)

- Savings of bandwidth is possible by varying the number of bits used for the difference signal depending on its amplitude (fewer bits to encode smaller difference signals)
- An international standard for this is defined in **ITU-T recommendation G721**
- This is based on the same principle as the DPCM except an eight-order predictor is used and the number of bits used to quantize each difference is varied
- This can be either 6 bits – producing 32 kbps – to obtain a better quality output than with third order DPCM, or 5 bits- producing 16 kbps – if lower bandwidth is more important

Audio Compression- ADPCM subband encoder and decoder schematic



- The principle of adaptive differential PCM varies the number of bits used for the difference signal depending on its amplitude

Adaptive differential PCM (ADPCM)

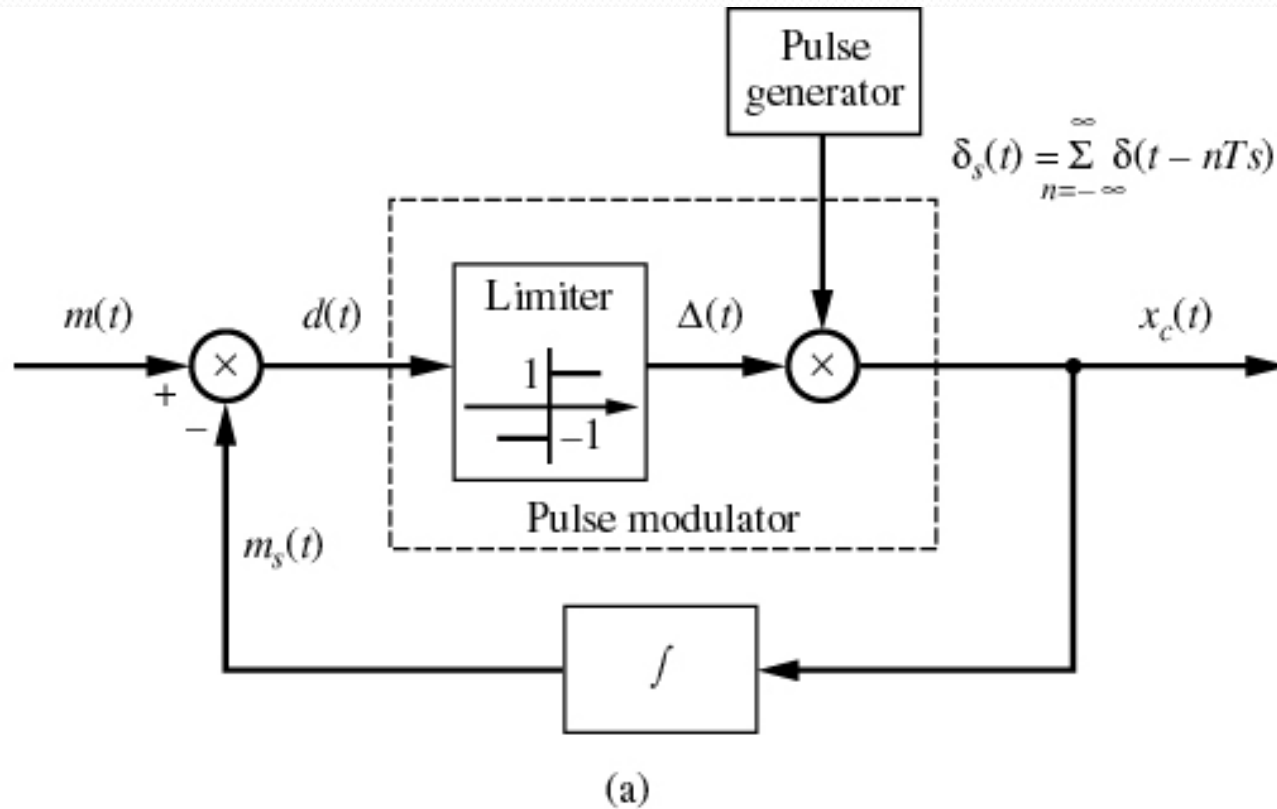
- A second ADPCM standard which is a derivative of G-721 is defined in ITU-T Recommendation G-722 (better sound quality)
- This uses *subband* coding in which the input signal prior to sampling is passed through two filters: one which passes only signal frequencies in the range 50Hz through to 3.5kHz and the other only frequencies in the range 3.5kHz through to 7kHz
- By doing this the input signal is effectively divided into two separate equal-bandwidth signals, the first known as the *lower subband signal* and the second the *upper subband signal*
- Each is then sampled and encoded independently using ADPCM, the sampling rate of the upper subband signal being 16 ksps to allow for the presence of the higher frequency components in this subband

Adaptive differential PCM (ADPCM)

- The use of two subbands has the advantage that different bit rates can be used for each
- In general the frequency components in the lower subband have a higher perceptual importance than those in the higher subband
- For example with a bit rate of 64 kbps the lower subband is ADPCM encoded at 48kbps and the upper subband at 16kbps
- The two bitstreams are then multiplexed together to produce the transmitted (64 kbps) signal – in such a way that the decoder in the receiver is able to divide them back again into two separate streams for decoding

Baseband Transmission

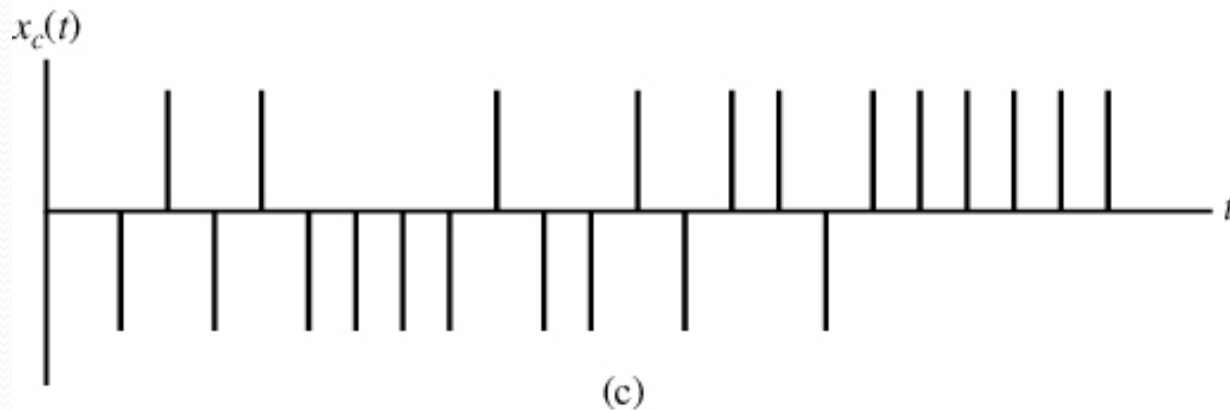
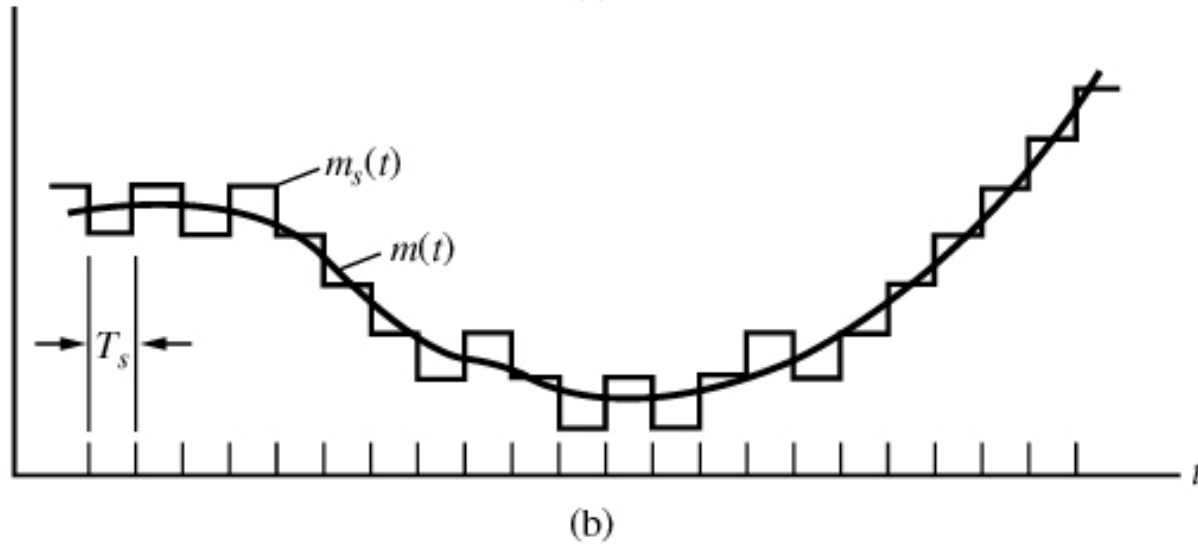
Delta Modulation (DM)



DM transmitter

Baseband Transmission

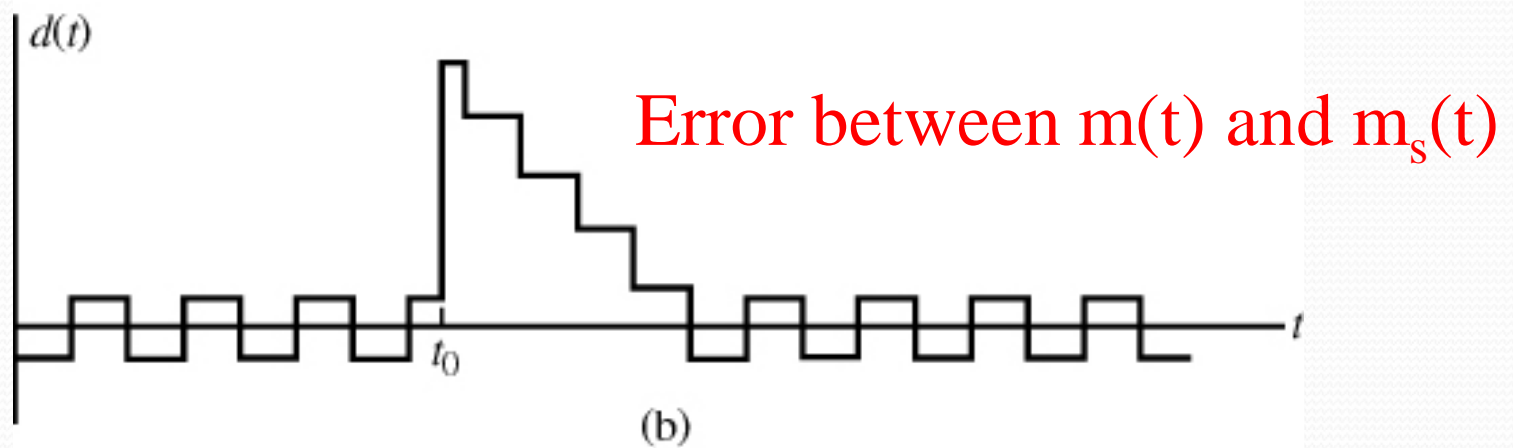
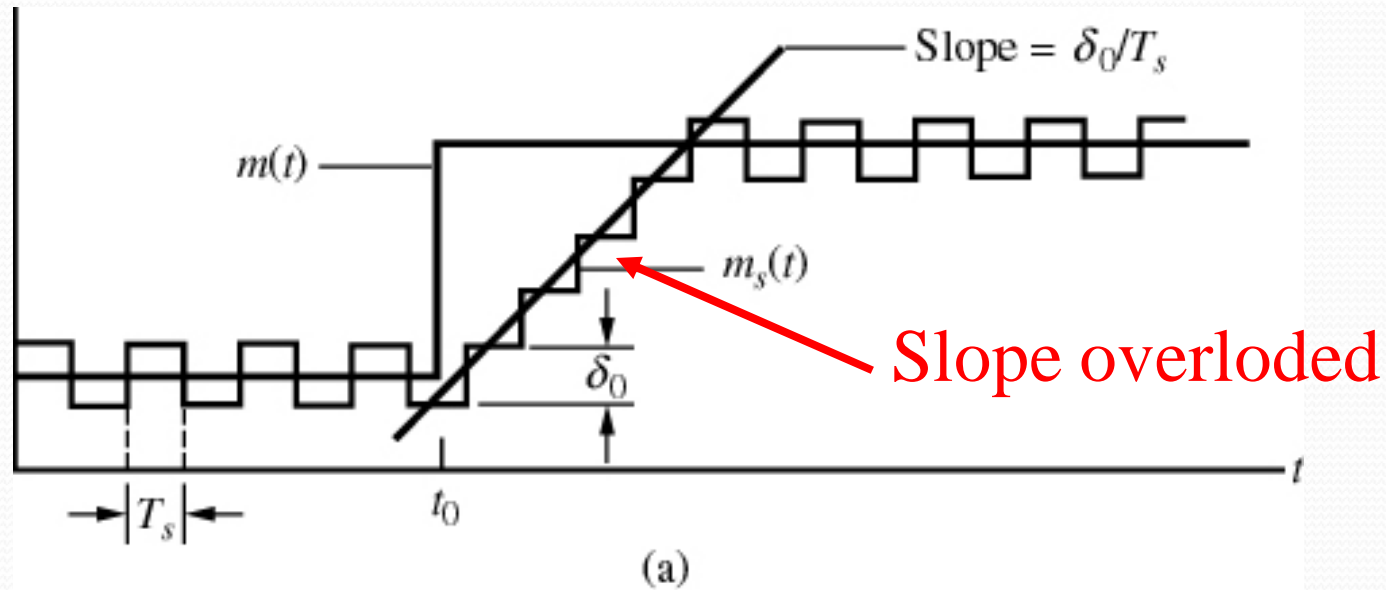
Delta Modulation (DM)



DM waveforms

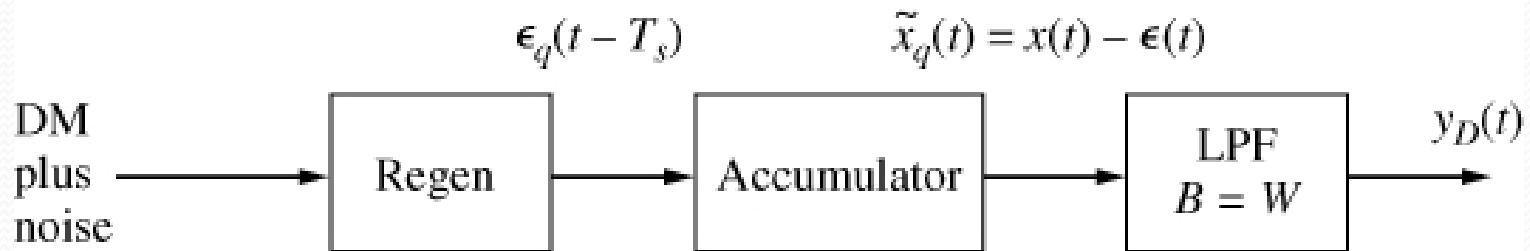
Baseband Transmission

Delta Modulation (DM)

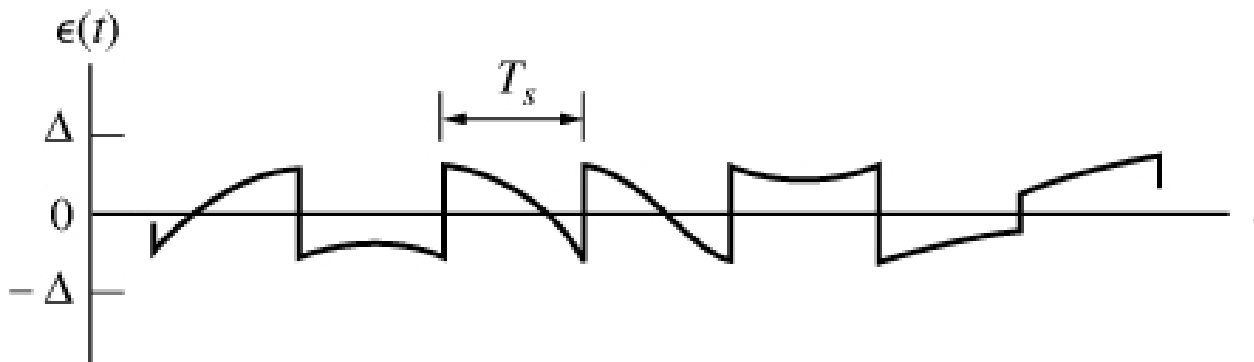


Baseband Transmission

Delta Modulation (DM)



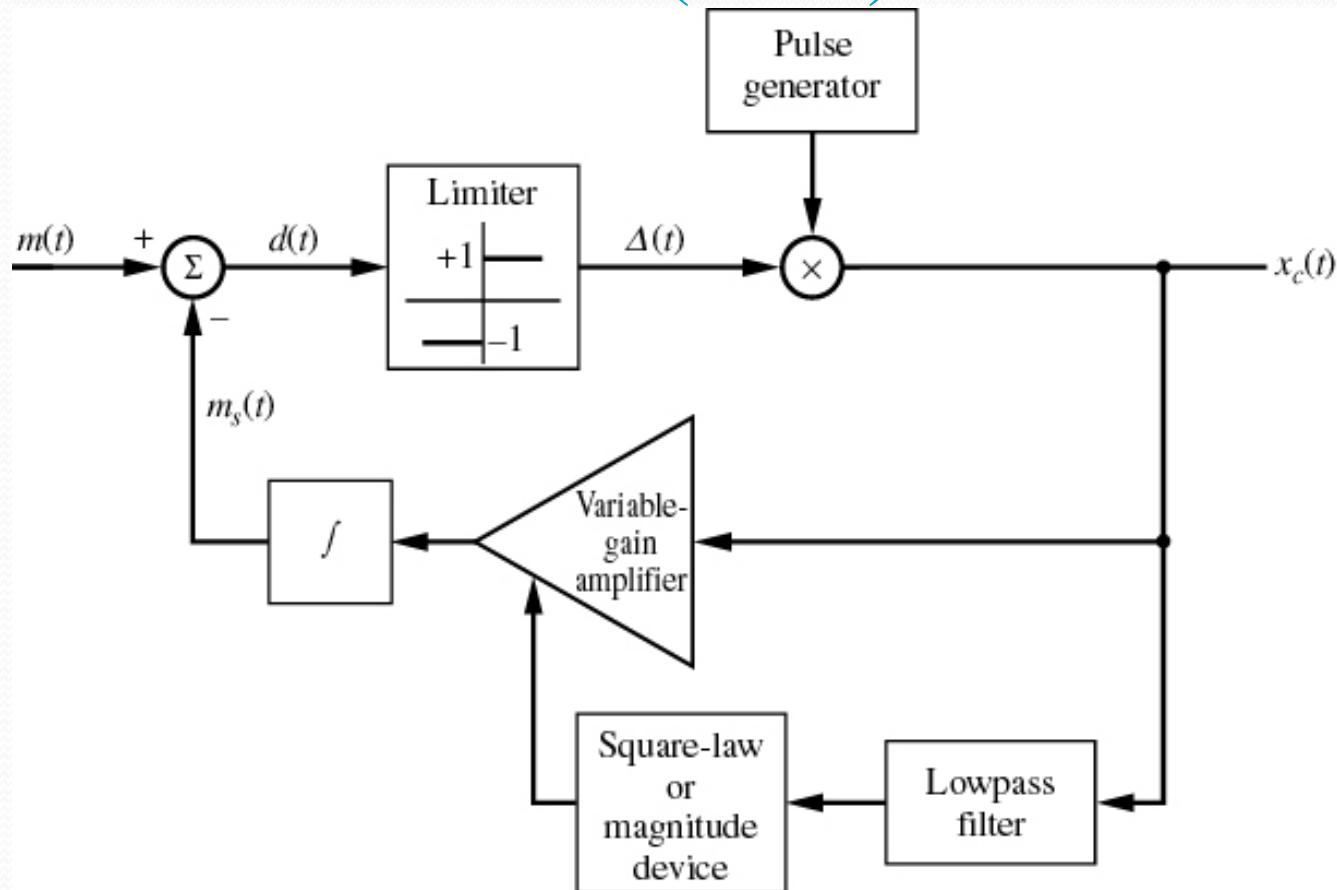
DM receiver



Granular noise waveform

Baseband Transmission

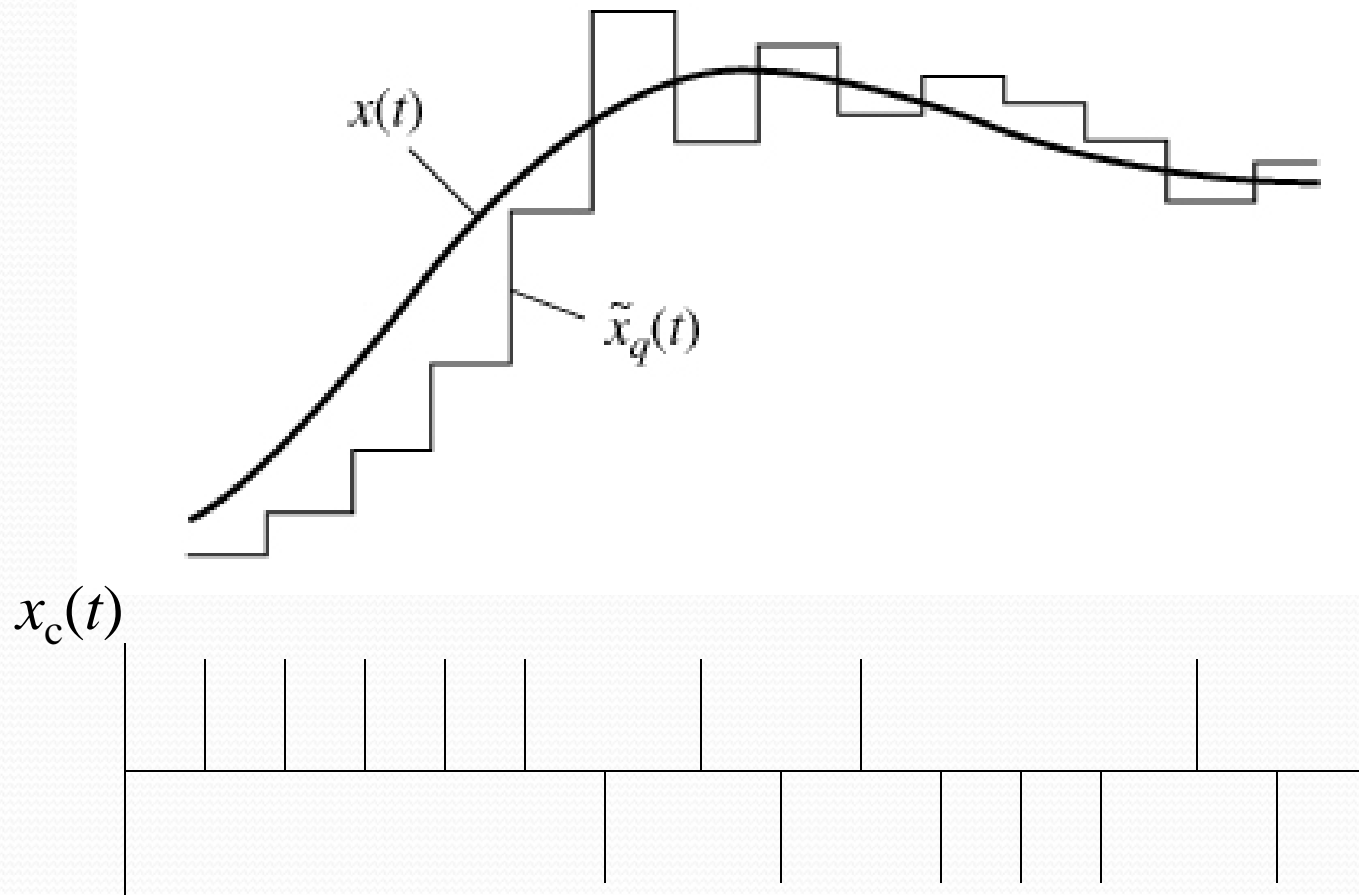
Adaptive Delta Modulation (ADM)



ADM transmitter

Baseband Transmission

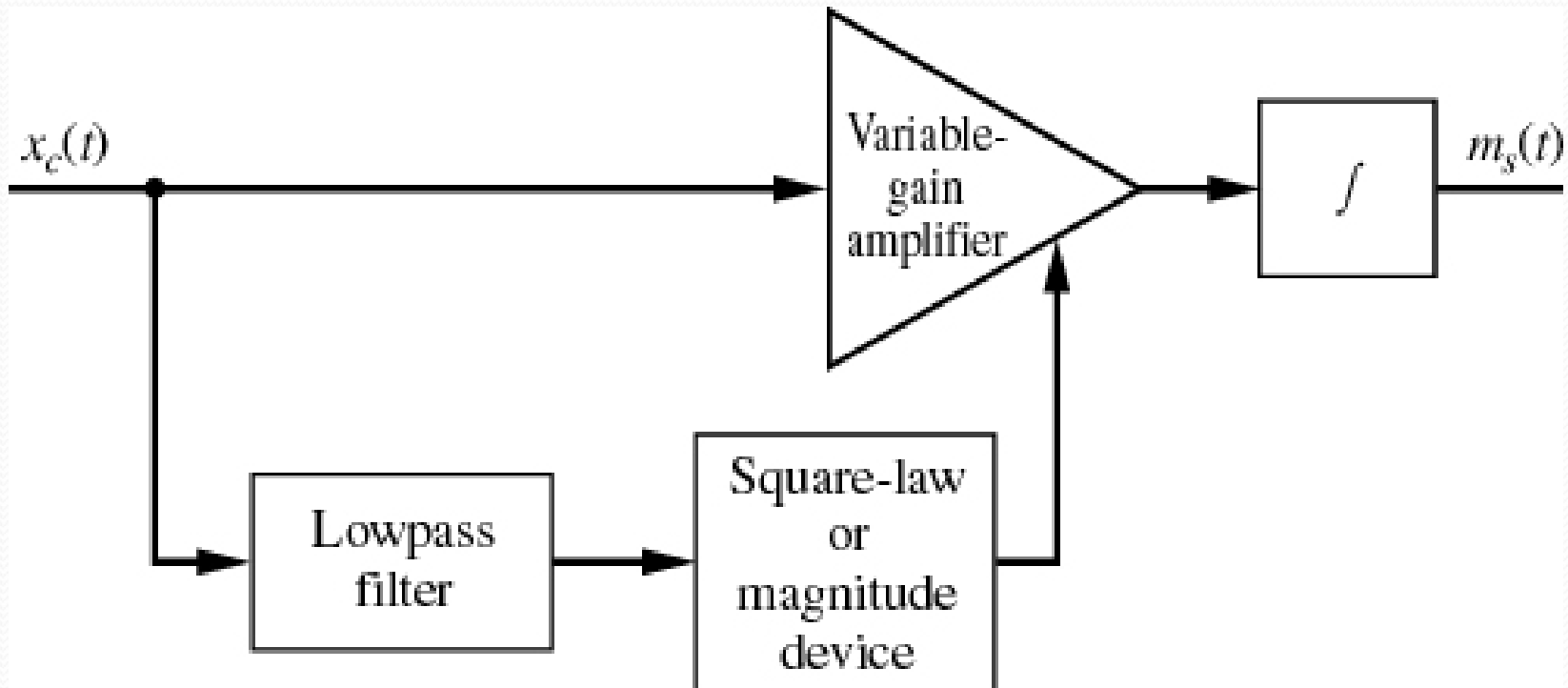
Adaptive Delta Modulation (ADM)



ADM waveforms

Baseband Transmission

Adaptive Delta Modulation (ADM)



ADM receiver